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Characterizing Green Fiber Bottle prototypes using Computed Tomography

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Abstract
Due to ever increasing demand of sustainability and biodegradability, there arises a need to develop environmental friendly packaging products. Green fiber bottle is a packaging product for carbonated beverages, made out of cellulose fibers. The production process accounts for moulding paper pulp in the desired shape and structure. However, there are certain limitations associated to the product characterization using tactile measuring methods. In this work, a new approach has been applied for defect analysis and quality control of non-homogenous prototype paper products using computed tomography.

Keywords: Computed tomography, Paper products, Porosity analysis, Quality control, Thickness analysis

1 Introduction

The use of XCT (X-ray Computed Tomography) in paper industry is not wide-spread. With a growing concern for sustainability of consumer products, paper is being considered for large number of applications. The Green Fiber Bottle is a biodegradable paper bottle that finds its application for carbonated beverages [1]. The product being non-homogeneous in nature demands a reliable product quality characterization technique. Non-contact 3D scanning techniques such as computed tomography can be utilized for improving the quality of packaging products.

2 Material and Method

Paper bottles of the desired geometry were produced using recycled newprint paper pulp of consistency 0.01. Thus, 3 kgs of newspaper are mixed in 300 litres of water and continuously stirred. Figure 1 shows the propototype of green fiber bottle. The specimens were divided into three regions of interest for the XCT analysis.

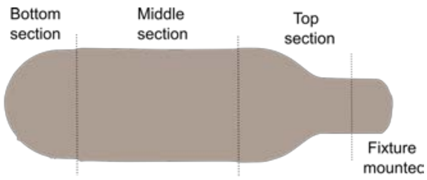

Figure 1: Prototype of the Green Fiber Bottle (GFB)

2.1 Manufacturing Process

The moulding process was carried out in two steps, in the first step the pulp slurry was injected in a forming tool as shown in Figure 2. A fine wired mesh is provided on the inner surface while the holes are drilled onto the outer surface. Water is evacuated by the use of a compressor which creates vacuum and also allows a control of the deposition of the pulp layer. The wet bottle is

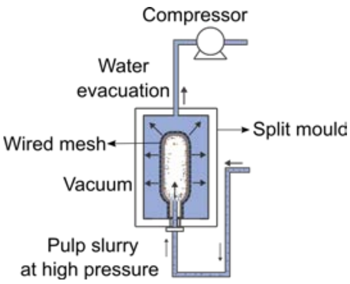

Figure 2: The forming process

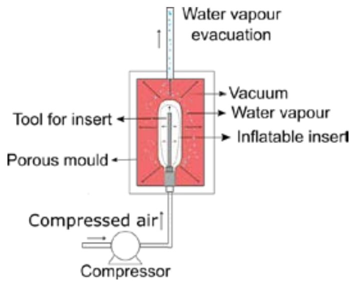

Figure 3: The drying process

then transferred to a drying tool which is preheated up to 140°C (Figure 3). The tool is made up of porous aluminium, as vacuum is applied from outside, water which converts to steam rushes out. At the same time a silicone insert exerts pressure on the bottle from inside of the tool to avoid shrinkage of paper during drying.

2.2 Measurements on industrial CT scanner

Measurements were conducted on a Nikon XT H 225 CT available at Technical University of Denmark. Scanning parameters are reported in table 1. The paper bottle was mounted on a cylindrical aluminium fixture ensuring good stability over scanning. The workpiece was scanned four times in a row in order to quantify the repeatability. A copper target was set for this investigation, instead of the tungsten target normally used, because of its advantages in ensuring better contrast at low powers. Due to its large dimensions, the bottle was mounted on an aluminium fixture. No physical filter was used for minimizing the beam hardening. Detector calibration was performed using a total of 64 projections evenly distributed over four different power levels. Just few power levels were sufficient for the correction due to the limited broadness of the X-ray spectrum used and the constant absorption values of the materials across the entire X-ray spectrum.

Table 1: Overview of scanning parameters

Parameter	Unit	Value
X-ray tube voltage	kV	80
X-ray tube current	µA	100
Corrected voxel size	µm	100
Magnification factor	-	1.7
Number of projections	-	1500
Number of images for projection	-	2
Integration time	s	1

No workpiece displacement during measurement was observed by superimposing the last projection onto the first one. Surface determination was based on a local thresholding method implemented in VG studio Max 3.0. This method currently represents the state-of-the-art tool for segmenting CT data sets allowing to reach about 1/10 of a voxel in terms of measurement uncertainty [2]. Sensitivity analysis was conducted to take into account the effect of the noise on the surface determination.

3 Quality control

CT scanning of fibrous materials such as paper on the macro scale can give a very precise measure of the dimensions of the product such as roundness, thickness, angles etc. and can also look at the internal defects in the product such as voids, inclusions etc. which may occur due to inhomeginity of the paper product. This is useful in designing the product as well as evaluating the production method itself. Paper being a softer material, doesn't offer a possibility of tactile measurements for quality control, and thus XCT finds it's importance in moulded pulp products manufacturing [3].

4 Results and Discussion

Porosity analysis, thickness analysis and Nominal/Actual comparison was carried out for the bottle prototypes. The results reveal, large number of pores were located in the neck section, which indicate non-uniformity in pulp distribution.Variation in thickness at different heights indicate non-uniform compaction of pulp fibers. Traceability of measurement results is also discussed in the work.

Acknowledgements

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